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Project: Continuation of Studies into the Variation of Motion Resistance of Whole Blood with Variations on Hydrostatic Pressure

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Final Report

Apparent Viscosities of Whole Blood Systems at Moderate Pressure

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Apparent Viscosity Determinations on Blood not Treated with Anticoagulants at Several Hydrostatic Pressures

1. Introduction

Here we can quote our last report introduction and simply delete the words treated with anticoagulants. The weight of evidence is again that the apparent viscosity of blood is unlikely to vary significantly with hydrostatic pressures to pressures of 775 psi (fifty atmospheres).

2. The Photographic Falling Projectile Viscometer

The evidence for asserting that whole blood not treated with anticoagulant shows no significant variation with hydrostatic pressure was accumulated with this unit. (See Table 1.) The unit was improved during the summer of 1971 by improving the operation of the valves and replacing the mechanical projectile clamp with a magnetic clamp. Performance of the unit improved tremendously with the introduction of the magnetic clamp although data obtained with this device shows slightly more scatter than most capillary data, the viscosity values obtained before blood coagulation (8.1 to 14.3×10^{-7} #-sec/in^2) compare well with viscosity values of 10.0×10^{-7} #-sec/in^2 obtained over all pressures at 98.0 to 100.0°F in the closed loop capillary device and to values in the neighborhood of 8.4×10^{-7}#-sec/in^2 obtained with the rheogoniometer at 37°C and atmospheric pressure. For the tests listed in Table 1 the first four were conducted with the chambers subjected to pressures of 25, 275 and 525 psi with chamber C always at 25 and chambers B and A sometimes at 275 and at 525 on other occasions. In test number 5 of Table 1 Chamber C was subjected to pressure of 275 psi, Chamber B to a pressure of 775 psi and Chamber A to a pressure of 525 psi. The variation in the data in Table 1 is attributable to the need to use a venturi shaped projectile in this unit and to the lack of honing of the walls of the test chambers.

All donors for these tests were found by the method of electrophoresis to have normal Beta-lipoproteins. There was furthermore no indication of any influence of hydrostatic pressure on clotting time of blood. Some clotting times obtained were long but such long clotting times always appeared at all hydrostatic pressures and were attributed in the most significant case (Test 4) to a possible residue of silicone oil in the unit from a test the preceding day with silicone oil.

3. The Bulk Modulus Tester

A limited set of tests were conducted with a bulk modulus tester which consists of a piston driven into a closed teflon lined chamber connected to a pressure transducer. The tests reached levels of pressure of 1650 psi and above and were designed to provide information on whether addition of sufficient mechanical potential energy to whole human blood not treated with anticoagulants could trigger chemical reactions in the blood. If the p versus $\Delta V/V$ curve had been concave down there would be indication of loss of mechanical potential energy as the piston moved into the blood. As can be seen, however, from Figure 3 the plot of p versus $\Delta V/V$ is a straight line in the linear range of the CEC pressure transducer (above 200 psi), and there is no indication of any decay of mechanical potential energy in the bulk compression of the blood. Figure 3 shows a bulk compression test conducted with water to obtain a calibration for the CEC transducer. Two points on the pressure axis were obtained by subjecting the bulk modulus container to known pressures on a dead weight tester, and the remainder of the pressure scale was computed from the two base points using the known bulk properties of water.

Again the conclusion no discernible effect of hydrostatic pressure on whole human blood emerges.

4. The Transistorized Falling Ball Viscometer

In addition to the preceding units and tests we have

developed a transistorized falling ball viscometer designed to eliminate the problems that develop with photographic falling projectile viscometer. (For details on this unit see Appendix A of this report.) We have not been able to use the unit with blood as yet, but in the next two weeks we shall have tests with blood, and we shall then check the photographic unit data with the falling ball unit which we expect to give better performance due to a diminished tendency toward leaks and a less quixotic projectile.

5. Analytical Work

In addition to the experiments so far presented Dr. R. Marshall of NCE was added to the project in place of the graduate student who could not be found. Dr. Marshall was commissioned to seek mathematical descriptions of potential mechanisms for producing apparent viscosity changes as a result of chemical reactions in plasma. The work showed some promise but was abandoned when no significant conversion of mechanical to chemical energy as a result of subjecting blood samples to hydrostatic pressure could be detected experimentally.

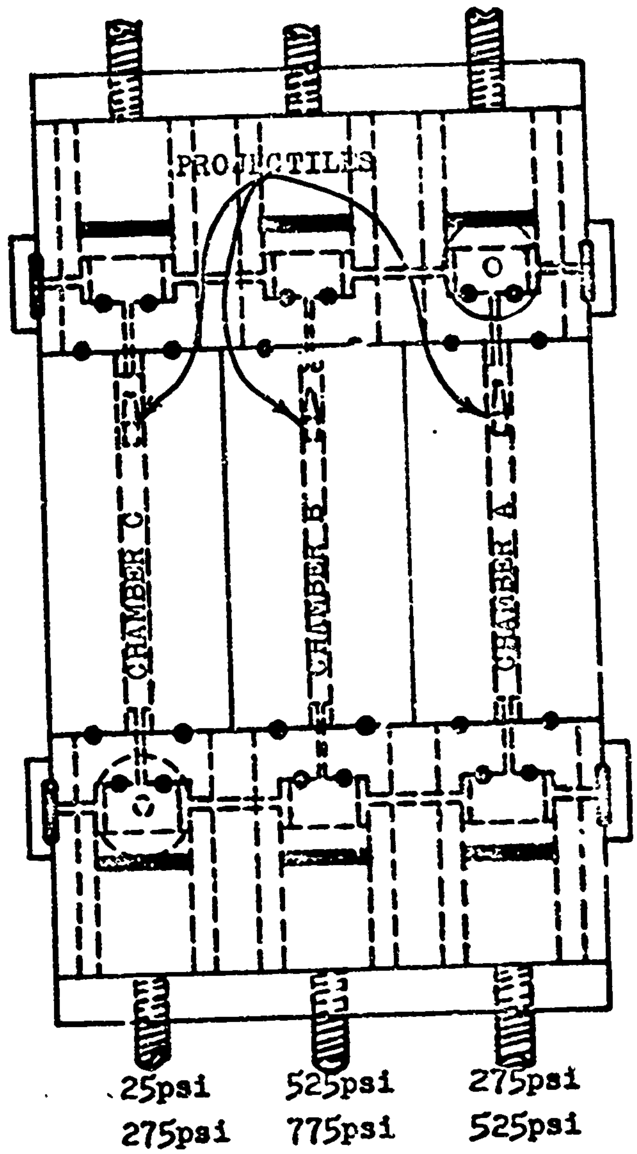

PROJECTILES
CHAMBER C
CHAMBER B
CHAMBER A
25psi
275psi
525psi
775psi
275psi
525psi

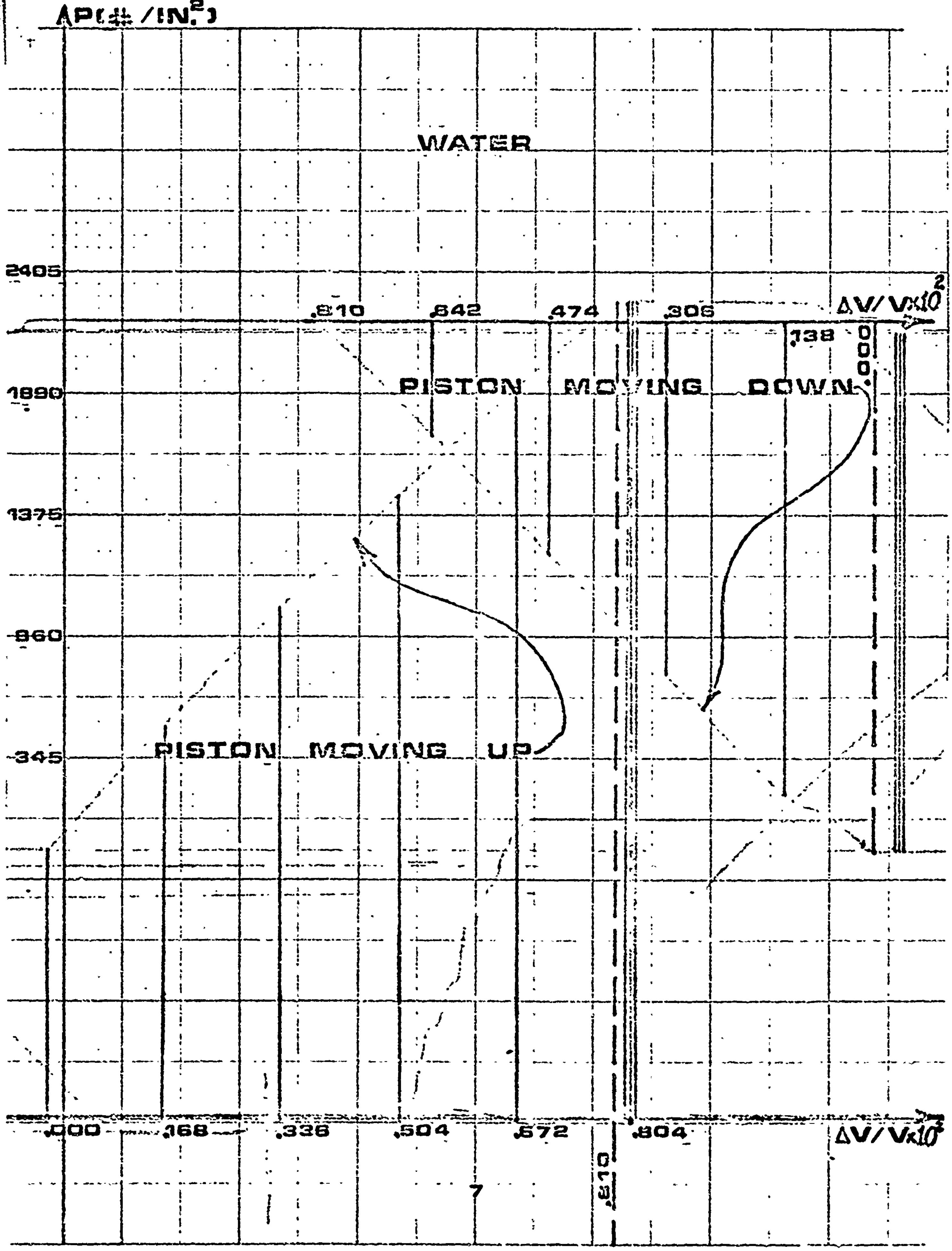
FIGURE 1

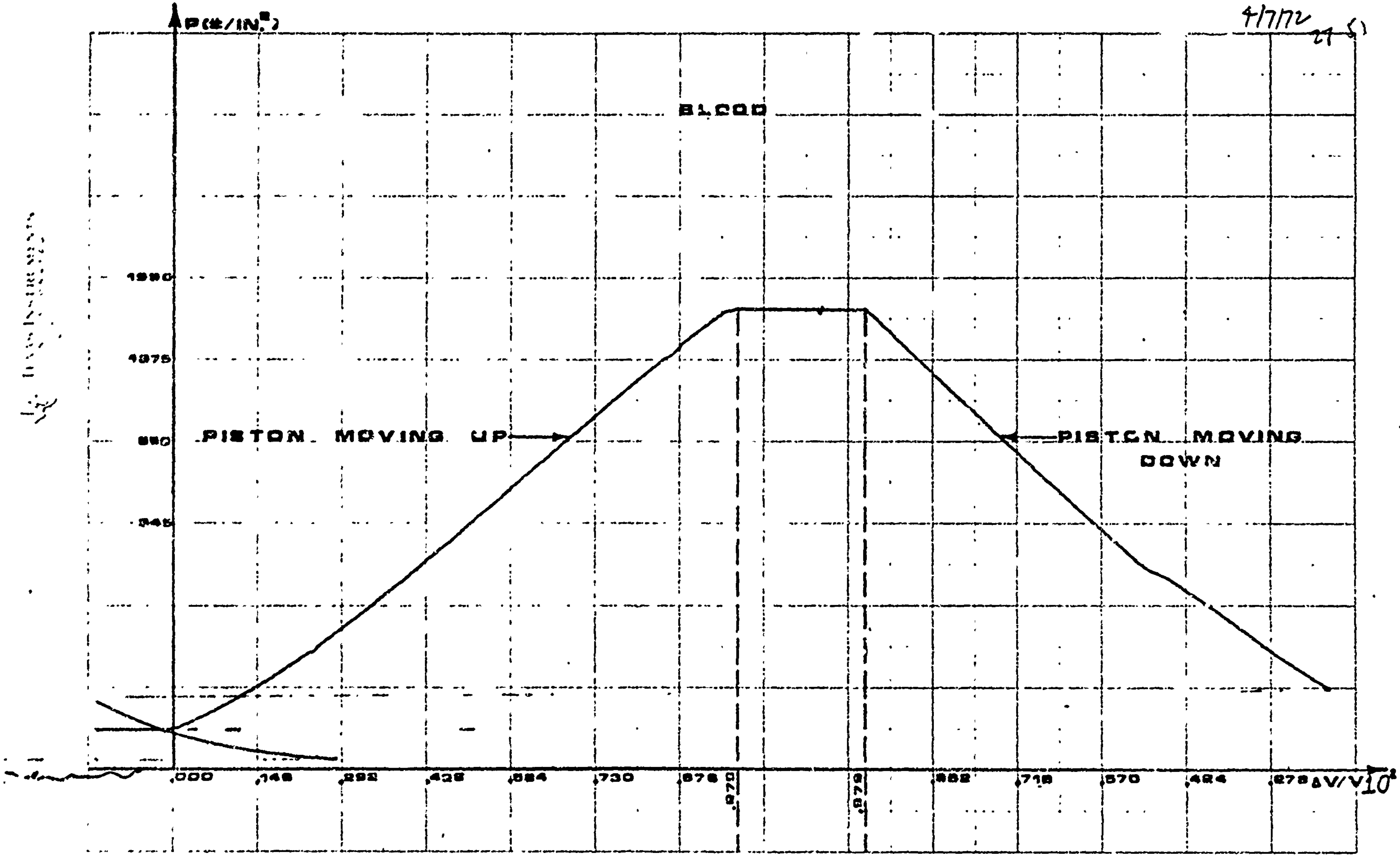
Table 1

Test	Temp.	Chamber C	Chamber B	Chamber A	
1	77.5°F	3.2	3.2	3.4	Term Vel in/sec
		13.2×10^{-7}	10.7×10^{-7}	13.0×10^{-7}	Apparent Viscosity #-sec/in^2
2	77.5°F	3.2	3.6	3.7	Term Vel in/sec
		13.2×10^{-7}	8.1×10^{-7}	10.1×10^{-7}	Apparent V #-sec/in^2
3	76.5°F	3.1	3.1	3.5	Term Vel in/sec
		14.3×10^{-7}	11.7×10^{-7}	12.1×10^{-7}	Apparent V #-sec/in^2
4	76.0°F	3.4	3.4	3.5	Term Vel in/sec
		11.2×10^{-7}	9.2×10^{-7}	12.1×10^{-7}	Apparent V #-sec/in^2
5	81.5°F	3.6	3.5	3.4	Term Vel in/sec
		9.3×10^{-7}	8.6×10^{-7}	13.0×10^{-7}	Apparent V #-sec/in^2

Table 2

Test	Chamber C			Chamber B			Chamber A		
	Coag. Time	Pressure	Temp.	Coag. Time	Pressure	Temp.	Coag. Time	Pressure	Temp.
#1	6 min 35 sec	25#/in^2	77.5°F	6 min 35 sec	275#/in^2	77.5°F	6 min 35sec	525#/in^2	77.5°F
#2	5 min 45 sec	25#/in^2	77.0°F	5 min 45 sec	275#/in^2	77.0°F	5 min 45 sec	525#/in^2	77.0°F
#3	7 min 35 sec	25#/in^2	76.5°F	7 min 35 sec	275#/in^2	76.5°F	7 min 35 sec	525#/in^2	76.5°F
#4	4 min 55 sec	25#/in^2	76.0°F	4 min 55 sec	275#/in^2	76.0°F	4 min 55 sec	525#/in^2	76.0°F
#5	9 min 6 sec	25#/in^2	81.5°F	9 min 6 sec	525#/in^2	81.5°F	9 min 6 sec	275#/in^2	81.5°F


ΔP(#/IN.²)
WATER
2405
1890
1375
860
345
.810
.842
.474
.306
.138
000
ΔV/V×10²
PISTON MOVING DOWN
PISTON MOVING UP
.000
.168
.336
.504
.672
.804
.810
ΔV/V×10²


P(#/IN.²)
4/7/72
BLOOD
1950
1375
850
345
PISTON MOVING UP
PISTON MOVING DOWN
.000
.146
.292
.438
.584
.730
.876
.970
.972
.862
.718
.570
.424
.278
ΔV/V 10²

Appendix A

TRANSISTORIZED FALLING BALL VISCOMETER

This exhibit presents a transistorized falling ball viscometer designed for testing of human blood samples not treated with anti-coagulant at three hydrostatic pressures. Changes in reflected light produced as the ball passes optically sensitive transistors spaced .330 in. center to center produce electrical outputs from the transistors which are recorded on a Texas Instrument Function Writer. From the recorded trace the time of travel of the ball between center lines of transistors can be determined, and the terminal velocity of the balls can be estimated.

In Figure 1 is shown a line drawing of the unit. The unit has been operated with G. E. Silicone Oils at various temperatures, and the results are recorded in Tables I, II, and III. From Tables I , II and III, calibration curves for each of the chambers have been drawn, and those curves are shown in Figures 4, 5 and 6.

While the unit is designed for use with whole blood, the unit can also be used for rapid simultaneous determinations of viscosities of one or several technological fluids.

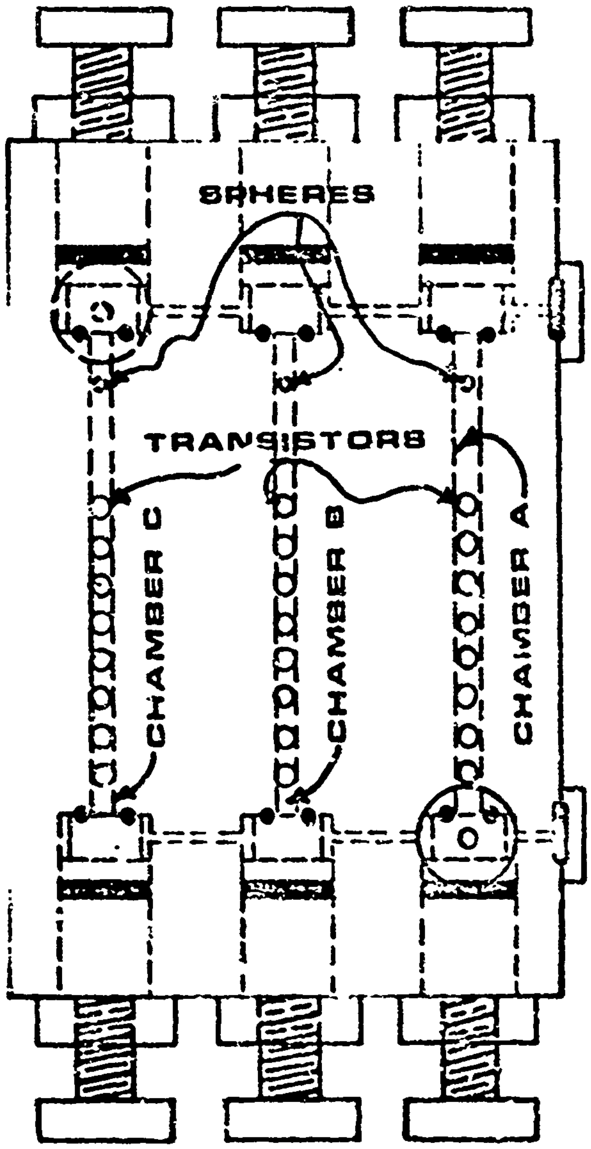


FIGURE 1

Calibration Chart

Chamber C

Fluid	Temperature °F	Viscosity x10^{7} #-sec/in^{2}	Velocity in/sec
GE SF 96 (5)	117.0°	4.3	7.89
	117.0°	4.3	8.14
	117.0°	4.3	7.84
	117.0°	4.3	7.90
	117.0°	4.3	7.70
GE SF 96 (10)	112.0°	8.6	6.[illegible]2
	114.0°	8.5	6.50
	114.0°	8.5	6.56
	117.0°	8.1	6.41
	117.0°	8.1	6.25
	117.0°	8.1	6.50
	117.0°	8.1	6.58
	118.0°	8.1	6.62
GE SF 96 (20)	107.5°	17.0	3.14
	107.5°	17.0	3.18
	119.0°	15.9	4.33
	119.0°	15.9	4.14
	119.0°	15.9	4.16
	119.0°	15.9	4.41
	119.0°	15.9	4.25
	119.0°	15.9	4.22
	119.0°	15.9	4.28

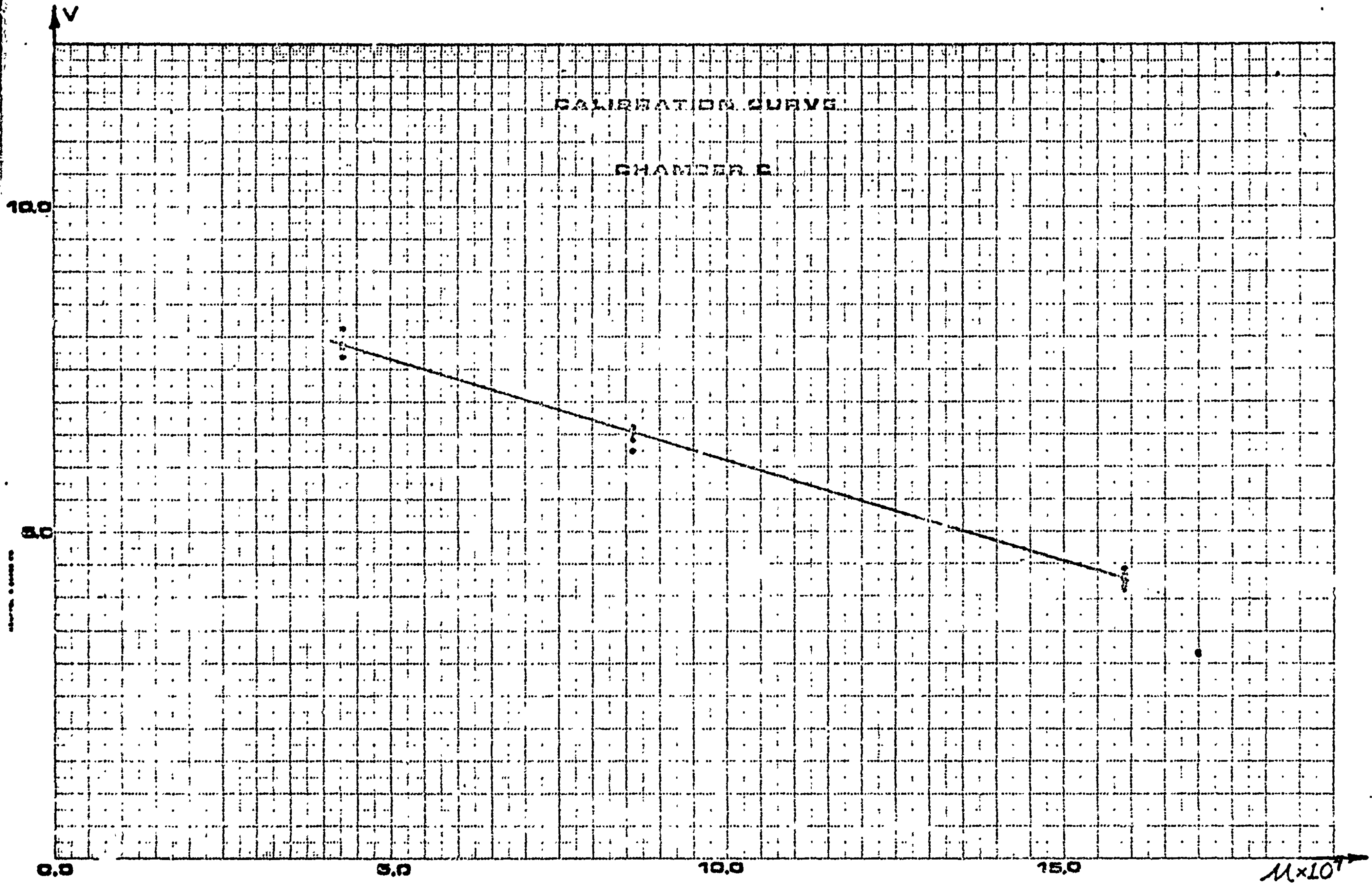
Calibration Chart

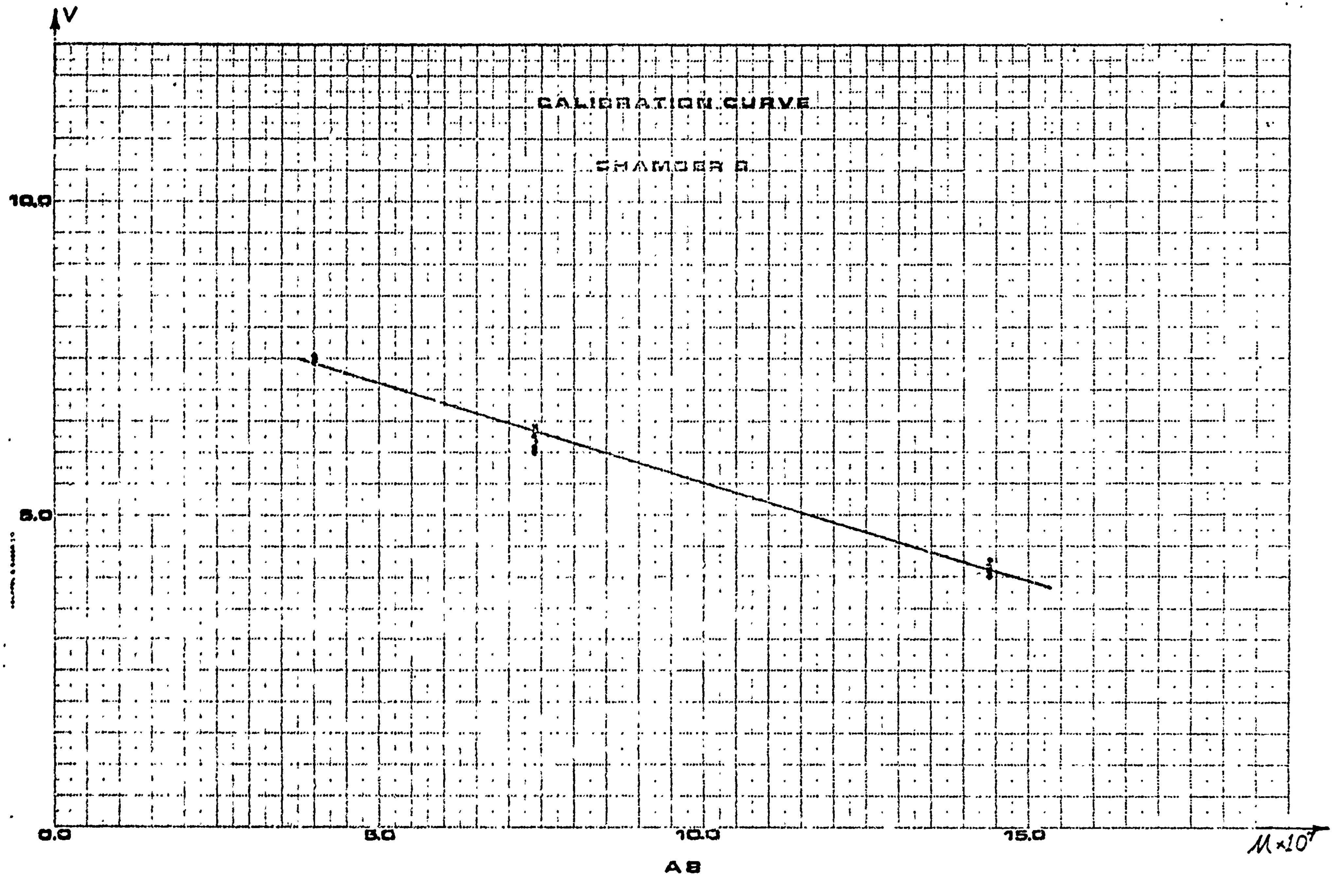
Chamber B

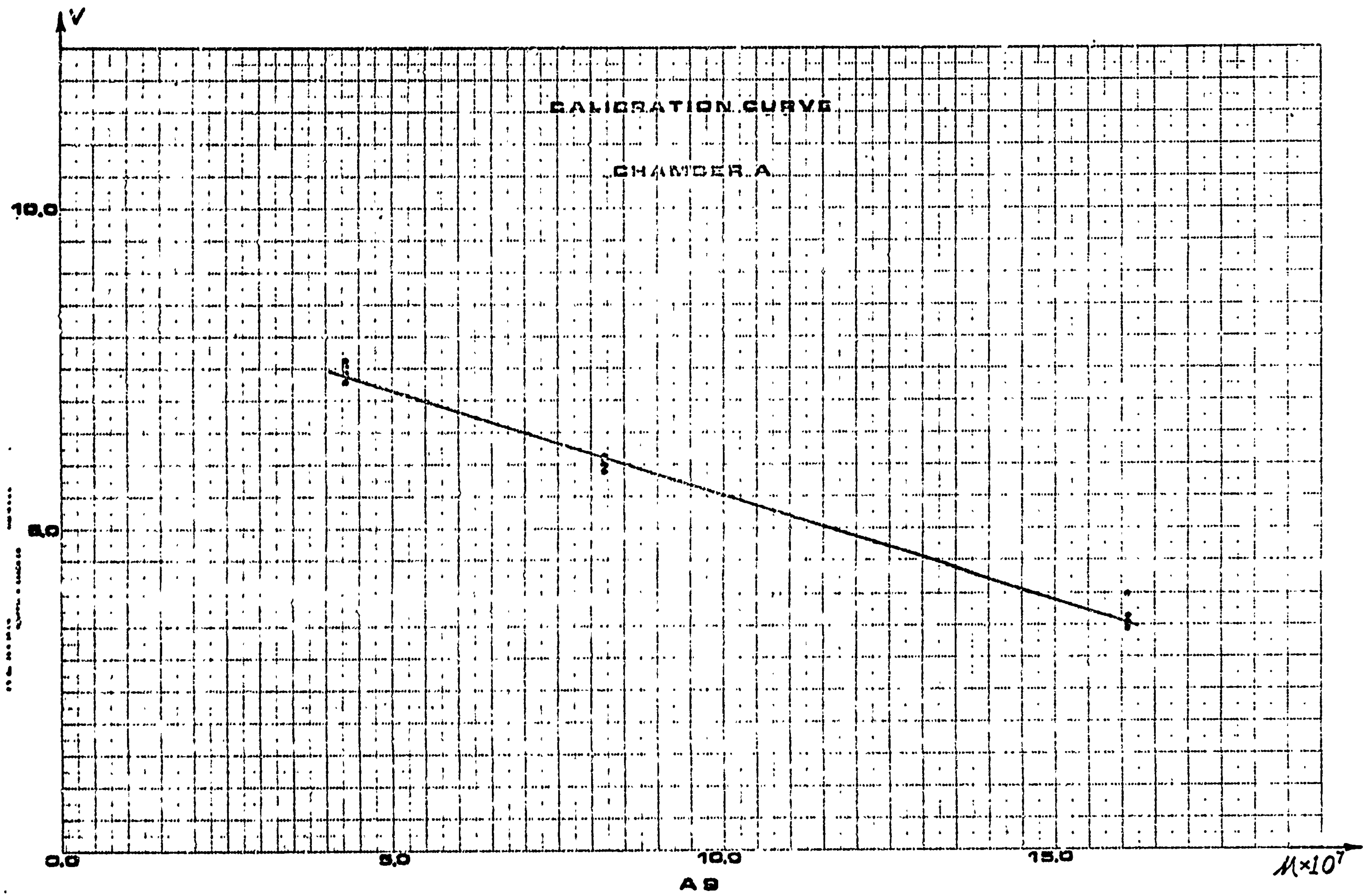
Fluid	Temperature ^{o}F	Viscosity x10^{6} #-sec/in^{2}	Velocity in/sec
GE SF 96 (5)	122.0°	4.0	7.44
	122.0°	4.0	7.55
	122.0°	4.0	7.50
	122.0°	4.0	7.55
GE SF 96 (10)	126.0°	7.4	6.05
	126.0°	7.4	6.20
	126.0°	7.4	6.43
	126.0°	7.4	6.17
	126.0°	7.4	6.14
	126.0°	7.4	6.00
	126.0°	7.4	6.25
	126.0°	7.4	6.37
	126.0°	7.4	6.32
GE SF 96 (20)	132.0°	14.4	4.06
	132.0°	14.4	4.15
	132.0°	14.4	3.99
	132.0°	14.4	4.20
	132.0°	14.4	4.16
	132.0°	14.4	4.11
	132.0°	14.4	4.27
	132.0°	14.4	4.06
	132.0°	14.4	4.15

Calibration Chart
Chamber A

Fluid	Temperature °F	Viscosityx10^{4}-sec/in^{2}	Velocity in/sec
GE SF 96 (5)	115.0°	4.3	7.50
	114.0°	4.3	7.53
	114.0°	4.3	7.58
	114.0°	4.3	7.28
	114.0°	4.3	7.61
	114.0°	4.3	7.43
	114.0°	4.3	7.53
	114.0°	4.3	7.40
	114.0°	4.3	7.60
GE SF 96 (10)	116.0°	8.2	5.98
	116.0°	8.2	5.88
	116.0°	8.2	6.03
	116.0°	8.2	6.05
	116.0°	8.2	6.09
	116.0°	8.2	6.00
	116.0°	8.2	6.14
	116.0°	8.2	6.08
	116.0°	8.2	6.06
GE SF 96 (20)	116.0°	16.1	3.47
	116.0°	16.1	3.99
	116.0°	16.1	3.51
	116.0°	16.1	3.52
	116.0°	16.1	3.55
	116.0°	16.1	3.56
	116.0°	16.1	3.44
	116.0°	16.1	3.64
	116.0°	16.1	3.54


CALIBRATION CURVE
CHAMBER C
V
10.0
5.0
0.0
5.0
10.0
15.0
$\mu \times 10^7$


CALIBRATION CURVE
CHAMBER B
V
10.0
5.0
0.0
5.0
10.0
15.0
μ×10^7
AB


CALIBRATION CURVE
CHAMBER A
V
10.0
5.0
0.0
5.0
10.0
15.0
$M \times 10^7$
A9